ACRP REPORT 25

Airport Passenger Terminal Planning and Design

Volume 1: Guidebook

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), and the Air Transport Association (ATA) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

tions representatives; local and state highway and transit officials; and private transportation providers who utilize airport facilities.

Ground access transportation planning at airports occurs on both a regional and a local scale. Regionally, the projected future needs of airport users must be taken into account during long-range planning processes and the strategic aspects will normally be considered in some depth during the Airport Master Plan development process. At a more detailed level, connections between components of the airport facility must be planned and designed to accommodate the expected traffic flows. Components of the ground transportation planning process are described in the following sections.

III.3.1 Regional Airport System Plan

The Regional Airport System Plan addresses air traffic demand and capacity, alternatives to meet future demand, air traffic forecasts, and environmental effects of airports on a regional basis. One of the most important parts of this document is the Ground Transportation Report. This report addresses the effects of increased aviation activity on ground traffic, the ground access improvements needed to support new airfield and terminal developments in the region, and a summary of existing and proposed improvements needed to support airport development.

III.3.2 Regional Transportation Plan

Each metropolitan area in the United States with a population greater than 50,000 has an MPO, which is responsible for coordinating transportation planning processes within its region. Under the requirements of federal transportation laws and regulations (SAFETEA-LU), the MPO has the responsibility to prepare a Regional Transportation Plan (RTP), often called a Long-Range Transportation Plan. The RTP covers a 20-year planning horizon and must be updated every 4 years in areas that have not attained or maintained requisite air quality standards and every 5 years for areas that have.

In development of RTPs, MPOs are encouraged to coordinate with local agencies and planning officials, including airport operators. Improvements to ground access facilities, in order to support airport operations, need to be programmed through the MPO process. Therefore, it is crucial for airports and MPOs to share information to increase the accuracy and efficiency of the planning process.

III.3.3 Airport Ground Access System

III.3.3.1 Roadway

The airport access road system, also known as the airport entrance/exit roadway system, connects the interior airport roads to the local and regional roadway system and is the point of transition between the local and regional roadway system and the airport terminal area. It will need to have the capacity to handle the volume of traffic for now and the future. This facility can vary from arterial roadways with traffic signal control to limited access/freeway type roadways at larger airports.

One of the main considerations to take into account in planning airport access roads is to make sure that they are used only by airport users. Non-airport traffic should be discouraged. Such traffic can best be discouraged by designing a roadway system that does not provide any incentive for other drivers to use the airport roadway, such as travel time advantages for drivers who are searching for a route to another destination. This roadway design needs to be given careful consideration in all types of traffic conditions. For instance, there may not appear to be any advantage during normal conditions, but an advantage may arise when traffic conditions on off-airport roadways are especially congested.

The best way to discourage non-airport traffic is to ensure that the only destination for the airport entrance road is the airport terminals and the other airport facilities. One of the ways that this is typically done is by employing a loop roadway that serves the terminals, parking, and other facilities.

Another important consideration is signage. A lot of information needs to be conveyed to drivers approaching the airport, including which airlines and flights are served by each terminal and which parking areas are open. Many passengers and visitors are infrequent users of the airport, so it is important to minimize the number of decisions to be made at any one point, as well as to provide adequate information sufficiently in advance of the decision points. Wayfinding signage should be simple and concise, with the amount of text on one sign limited to what can reasonably be digested quickly by a driver.

III.3.3.2 Rail

Connection to a regional rail transit system is a very important enhancement to the airport's ground access system. Connection to a regional system provides more flexibility for air travelers. It also provides an alternative means of access for airport, airline, and concession employees.

A main consideration in planning for a facility of this type is to place it as close as possible to the areas with the highest demand. Normally a regional rail system would connect to only one station on the airport. Rail connections, for example, should preferably deliver passengers directly to a dedicated airport station, rather than requiring them to take a bus or taxi to complete the journey. Figure III-2 depicts light rail transit to an airport. This station should ideally be located in the highest areas of passenger demand, such as a high-volume terminal. This location often involves significant design challenges, especially if the terminal is already built. Fitting a rail station in the terminal area can be very difficult. Not only do the station and the platform need space, but there also needs to be a lot of space for passenger circulation, fare collection, and queuing outside of the platform.

Given the space considerations, the airport rail station may need to be in a location away from the terminal, such as at a ground transportation center. From here the passengers and employees can walk to the terminals or connect to an on-airport bus or automated people mover system.

Courtesy of: © Steve Uzzell

Figure III-2.   Light rail transit at Minneapolis–St. Paul International Airport.

Another consideration in planning for regional rail stations is flexibility. New station and track locations should be placed so as not to restrict future growth and flexibility of airport facilities. While placing the station close to the major activity centers is desirable, it may restrict the ability to make adjustments to the layout in the future. Location of the station farther away from the terminal may maintain more flexibility for future improvements.

III.3.4 Intermodal Connections

Airports often become a point of convergence for many different modes of transportation including road, rail, and, in some cases, ferry. Increasingly, airport planners worldwide are seeing merit in encouraging the use of public transportation to access airports, in order to reduce road congestion and the amount of land required for the parking of private vehicles, and to facilitate travel for airport employees. Good connectivity between the airport terminal and the various public transportation modes is an essential component of this strategy.

During the planning process, the needs of the various airport user groups must be taken into account. Regular airport users will soon work out the most efficient mode of travel from their perspective, while first time users will place a high priority on assurance of getting to the terminal in good time for their flight. Ease of use and wayfinding are important in ensuring that various transport modes are used to their full potential. The need to make multiple transfers between modes before reaching the destination significantly reduces the likelihood of users selecting that mode.

Intermodal facilities on the airport provide for connections among different providers of ground access services. These facilities bring together access for private vehicles, taxis, limousines, on- and off-airport shuttle buses, local and regional bus service, and possibly on- and off-airport rail service. An intermodal facility located adjacent to the terminal has the advantage of being within convenient walking distance of the terminal. The most common type is the use of the terminal curbfront. In the case of multiple terminals, this curbfront location would require multiple facilities. One of the main planning considerations of this type of facility is signage and wayfinding. This type of facility is typically spread out along a long length of curbfront. It is important to direct passengers correctly into and out of the terminal and from, or to, whichever mode of transport they are using.

An intermodal facility located away from the terminal is often called a "ground transportation center" (GTC) and provides a centralized area for a variety of public transportation modes to pick up and drop off passengers. This option provides greater flexibility for expansion in the future than one located next to the terminal. The major planning consideration for a GTC is access to and from the terminals. Sometimes access can be achieved by positioning the GTC between two terminals and maintaining reasonable moving walkway–assisted walking distances. If distances are too long, however, a supplementary shuttle bus or people mover system becomes necessary. Both systems will require a change of mode for the passenger, which increases travel time. A bus system has a much lower initial capital cost and provides the most flexibility. A rail-based system has a higher initial capital cost but offers a higher quality of service than a bus system. If the demand is especially high, the rail system, such as an automated people mover (APM), should be considered seriously.

III.4 Terminal Site Planning

III.4.1 Airfield Considerations

The design and siting of the terminal complex requires an examination of the existing and future airfield layout requirements. The fundamental airfield-associated components that largely determine the terminal design and location include the Obstacle Clearance Surface requirements, taxiway/taxilane requirements, ATCT sight lines, runway exit locations, and other airfield design

standard considerations. Each aspect heavily relies on the type and size (or number) of aircraft operations expected to occur at the airport.

III.4.1.1 Taxiway and Taxilane Requirements

When designing the airfield and terminal complex, it is important to provide an adequate taxiway/taxilane network to provide flexibility in aircraft movements throughout the entire airport. The taxiway and taxilane network will provide for safe, efficient, and expeditious travel between airport facilities (passenger terminal, cargo structures, general aviation facilities, etc.) and the runway system. Specifically, the taxiways function as the airport's paved network for aircraft between the runways and the apron, while the taxilanes provide aircraft routes on the aprons between the taxiways and terminal gate positions. Both taxiways and taxilanes must follow appropriate dimensional criteria based on current FAA and International Civil Aviation Organization (ICAO) design standards. For more information on taxiway and taxilane definition and fundamental design requirements, see Section V.1.2, Aircraft Maneuvering and Separations.

III.4.1.2 Airport Obstacle Clearance Surface Requirements

Navigable airspace in the vicinity of airports is governed by FAR Part 77 standards, which exist to protect the airspace and runway approaches from obstacles and hazards to aircraft in flight. Planning and design of the terminal building must consider any potential effect to these imaginary surfaces. An optimum design configuration avoids or minimizes any significant penetration of the existing and future airport imaginary surfaces. Imaginary surfaces include the primary, approach, transitional, horizontal, and conical surfaces. See Section V.1.1, FAR Part 77 and TERPS Requirements, for further discussion of these imaginary surfaces. If intrusion into these surfaces occurs as a result of terminal development, marking and lighting of the obstruction should take place as described in FAA AC 70/7460-1, *Obstruction Marking and Lighting* (*18*).

The building restriction line (BRL) is used to identify suitable building area locations on airports. The BRL should encompass the runway protection zones, the runway object free area, the runway visibility zone, navaid critical areas, areas required for terminal instrument procedures, and ATCT clear line-of-sight.

III.4.1.3 Runway Visibility Zone

If there are intersecting runways, a clear line-of-sight between the ends of the runways is recommended. Terrain needs to be graded and permanent objects need to be designed or sited so that there will be an unobstructed line-of-sight from any point 5 feet above one runway centerline to any point 5 feet above an intersecting centerline, within the runway visibility zone. See FAA AC 150/5300-13, *Airport Design,* Section 503 (*15*) to determine the runway visibility zone.

III.4.1.4 Air Traffic Control Tower Sight Lines

A clear and unobstructed line-of-sight must exist between the ATCT and all runway approach paths and movement areas (runways and taxiways) on the airfield. This requirement warrants consideration during the terminal siting analysis and design so that interference between ATCT and critical runway, taxiway, and apron areas does not occur. Besides general building structure, aspects of terminal design for consideration include aircraft parking configurations, tail heights, and ramp lighting, because they can result in line-of-sight shadows for the ATCT. The controller must be able to, at a minimum, see the fuselage of all aircraft types operating on the airfield. Section V.1.3 presents additional information relevant to ATCT line-of-sight requirements.

III.4.2 Landside Considerations

The primary landside elements that are important in the design and location of a terminal are intermodal facilities, roadways, pedestrian facilities, and parking facilities. Because each of these

elements needs to be located very close to the terminal, they will have a great impact on how the terminal is situated and how it functions.

III.4.2.1 Intermodal Facilities

Intermodal facilities include regional transit links to the airport (such as light rail or heavy rail) and on-airport commercial vehicle staging areas. The primary considerations for regional rail links are the right-of-way needed for the trains, the station layout, and the access links between the station and the terminal. The rail right-of-way and station layout will typically be covered in the design standards for the entire rail system. These can be adapted for the airport environment. Access from the station may be horizontal (sidewalks, moving walkways, overhead walkways) or vertical (escalators, elevators, and stairs). Stations located more than ¼ mile from the station may require a separate transit link to the terminal.

There is more flexibility in the layout and location of commercial vehicle staging areas, because these areas are entirely under the control of the airport design team. They can be dispersed or consolidated. Further discussion of the requirements for intermodal connections is contained in Section VII.2.

III.4.2.2 Roadways

Depending on the size of the airport, many different types of roadways can affect the terminal. However, for most airports, the main ones will be the terminal approach roads, the terminal curbfront roads, and the recirculation roads. The terminal approach roads will widen out as they approach the terminal into the terminal curbfront roadway, which has the widest footprint. The terminal curbfront roadways need to provide for loading and unloading lanes at the terminal and for lanes to accommodate vehicles not stopping at the terminal. For a two-level terminal, the height of the upper level roadway should be a consideration in air flow for the lower level.

Recirculation roads deserve special consideration. They are roadways that allow drivers to leave the terminal and either come back to the same terminal curb or go to another level of the same terminal or to a different terminal. Typically recirculation roads are one-lane roadways, with a wide shoulder to accommodate bypass in case of a vehicle breakdown. The turning radius on these roadways is much tighter than on a typical roadway, and ramp slopes (for two-level terminals) may be steeper than typical roadways. Requirements for roadways are discussed in more detail in Section VII.3 and for terminal curbfronts in Section VII.4.

III.4.2.3 Pedestrian Facilities

Landside pedestrian facilities include sidewalks in front of the terminal and, in many cases, sidewalks in between curbfront lanes. These facilities increase the width of the footprint needed in front of the terminal and, consequently, have an impact on the siting of a terminal. Requirements for pedestrian facilities are contained in Section VII.4.1.

III.4.2.4 Parking Facilities

Typically only passenger parking facilities are located adjacent to the terminal. Other parking facilities (such as employee, rental car, and cell phone lots) are located away from the terminal. Passenger parking can be provided in surface lots, in a parking garage, or in a combination of both. Parking can be placed facing the terminal or on the side of the terminal. For busy airports, the parking lots or garages can take up almost as much land as the terminal itself. Parking facility requirements are presented in Section VII.5.

III.4.3 Utilities Considerations

Utilities can be classified into four main categories: water, sewerage, natural gas, and electric power. Existing terminal expansion or new terminal infrastructure projects should take into

All of these factors make for an interesting and challenging planning process on the landside. This complexity calls for the use of a lot of creativity in adapting traditional transportation planning techniques and the adoption of specialized techniques to be used at airports. With this complexity it is also important to consider wayfinding and signage early in the planning process of new or reconfigured airport terminal ground access systems.

For additional information, consult *ACRP Report 10* (*34*), which aims to develop new concepts that will stimulate design innovation for terminal landside facilities.

VII.1 Transportation/Traffic Planning

Airport ground access networks are complex systems of interrelated facilities serving a variety of users. Therefore, planning for these systems requires a large and complex set of data, covering all of the components of the ground access system. This section presents the outline for data collection, the analysis and evaluation of the existing facilities, and the planning for new or upgraded facilities.

VII.1.1 Data Collection

The objective of a data collection program for ground access facilities is to gather the information necessary to determine existing and future adequacy of the ground transportation systems. Data that may be needed for this analysis and evaluation process includes the following:

- Inventory of physical characteristics—roads, parking, curbfronts, transit, and so forth.
- Existing O&D airport passenger activity
- Employee shift data
- Mode split data (private automobile, bus, train, taxi, etc.)
- Vehicular traffic counts
- Curbfront data—vehicle dwell times, occupancy, vehicle classification
- Parking information—passenger parking, employee lots, rental car, and so forth
- Commercial vehicle activity—taxis, limousines, courtesy vehicles, and so forth
- Rental car activity
- Public transportation information—buses, trains

A data collection program may include all of the data listed above or a subset of these, depending on the planning needs and what information is already available. As much as possible, all data, particularly count data, should be collected on the same day(s) and at the same time(s), so that it is as consistent as possible. Ideally, data should be collected during an average day in the peak month (PMAD).

If it is not possible to collect data during the peak month, it should be collected for an average day during another month, avoiding holidays, peak travel times (like Spring Break), and special events. Data can then be adjusted to reflect the PMAD, according to the airport's flight schedules and passenger activity. Some information, such as parking activity and rental car activity, may be available from the operators of these facilities. Modern parking revenue control systems can provide a lot of data by hour on movements in and out of the passenger parking lots. Other data can be collected through interviews and observations, as described below.

VII.1.1.1 Passenger Survey

Airport passenger surveys are typically conducted at the beginning of an Airport Master Plan or at the beginning of a major airport development program. These surveys, which are described in Section IV.2.5, cover all aspects of air passengers' trips. Included in this survey are a set of questions oriented toward the landside portion of the O&D passenger's trip. However, this data may not

be available or may be out of date when a ground access study is being conducted. A survey of O&D passengers can be done to gather the few key items needed for the study. This type of survey can be conducted by interviews with departing passengers who are waiting at the gates. The information that needs to be gathered for ground access generally includes data about access modes and routes to the airport, such as the following:

- Mode of arrival at the airport (automobile, taxi, bus, etc.)
- Parking location (short term, long term, off airport, etc.)
- If automobile, number of people in vehicle
- Route used to access airport
- If automobile, route taken within the airport (to parking first, to terminal then to parking, etc.)
- Time of arrival before flight time

For additional information, consult *ACRP Synthesis 5 (46)*, which addresses ground access mode choice models and their role in airport planning and management.

VII.1.1.2 Traffic Counts

There are two primary types of traffic counts: automatic traffic counts and intersection turning-movement counts. Automatic traffic counts are typically conducted by a machine over a period of 24 hours or more and provide a count of total traffic passing through the count station in 15-minute increments. They are useful for determining total traffic throughout the day, as well as determining peaking characteristics for roadways. Ideally, for a comprehensive data collection program, counts would be conducted for all entrance/exit roadways and ramps, terminal approach roads, terminal curbfront roads, recirculation roads, parking lot and rental car area entrances/exits, and service roads on the airport property, as well as off-airport facilities providing airport access. Manual traffic counts may also be needed for areas that cannot be captured by automatic counters. These areas may include weaving and merging maneuvers.

Intersection turning-movement counts are conducted manually, typically for a 2- to 4-hour period covering the peak hour of airport and/or off-airport traffic (or for multiple peak periods, if more than one peak needs to be analyzed). Turning-movement counts should be conducted for on-airport signalized and major unsignalized intersections, and off-airport intersections that provide airport access.

VII.1.1.3 Parking Lots

For public parking lots, it is important to examine the number of spaces available in different parking lots (i.e., short term, long term, economy, valet) at different times of day. Typically, the capacity (total number of parking spaces) of the lot will be determined through a physical count, as-built construction drawings, or possibly through examination of aerial photography for surface lots. Then, the number of occupied spaces will be counted, preferably at several times of day (i.e., morning, mid-day, afternoon). It may also be useful to gather information such as the average parking stay for various lots, if such data is available from the parking operator.

Similar counts can be conducted for off-airport parking lots and employee parking lots. For employee lots, the counts are ideally conducted near a shift change time, when the number of vehicles in the lot is likely to be at a maximum.

VII.1.1.4 Curbfronts

Data collected for curbfronts typically includes vehicle volumes, vehicle classification, and dwell times. Curbfront observations should be conducted during peak times. Separate observations should be made for arrival and departure curbfronts, because the characteristics of the vehicles will differ. Total vehicle volumes can be determined through automatic traffic counts as described previously. However, depending on the curbfront configuration, not all vehicles passing by the

curbfront will necessarily stop. Vehicle classifications at curbfronts will include automobile, taxi, limousine, bus, hotel/motel shuttle, rental car shuttle, off-airport parking shuttle, and any other vehicle types that stop at the curbfront.

Dwell times are collected by surveyors with stopwatches, who measure the time from when the vehicle stops at the curb until the vehicle is ready to depart the curb. Dwell times are calculated separately for different vehicle classifications.

VII.1.2 Analysis and Evaluation

Analysis and evaluation of existing and future ground access conditions for airports require a variety of methodologies, each tailored to specific facilities.

Airports vary greatly in their size and layout, making it difficult to arrive at guidelines for the development of airport roadways. There are many standard traffic and roadway resources that can be used. The most widely used of these are the following:

- *Highway Capacity Manual 2000,* Transportation Research Board (TRB). This is the standard manual used by traffic engineers. It quantifies congestion and highway operations in such a way that rational solutions can be determined.
- *Manual on Uniform Traffic Control Devices* (MUTCD), 2003 Edition; United States Department of Transportation, Federal Highway Administration. The MUTCD defines the standards used by road managers nationwide to install and maintain traffic control devices on all streets and highways.
- *A Policy on Geometric Design of Highways and Streets,* 5th Edition; American Association of State and Highway Transportation Officials. This fifth edition of AASHTO's "Green Book" contains the latest design practices in universal use as the standard for highway geometric design.

The quality of a driver's experience when traveling on a roadway facility is often described using LOS, expressed as a letter between A (best) and F (worst). According to the *Highway Capacity Manual* (HCM), LOS "is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience" (*47*). Figure VII-1 shows LOS for roadways in graphical form, with descriptions of each level.

VII.1.2.1 Intersections

On-airport intersections are usually similar in geometry and operating characteristics to off-airport intersections and can typically be evaluated using the same techniques. The HCM is a manual produced by TRB that details methodologies for analyzing roadways and intersections and is the standard for roadway analysis, both in the United States and in many other nations. Analysis according to HCM procedures can be completed by hand but is more typically done using a commercially available software program such as Highway Capacity Software or Synchro. HCM methodologies use information including traffic volumes and roadway characteristics to rate the LOS of the intersection.

VII.1.2.2 Roadways

On-airport roadways typically differ in geometry and operating characteristics from off-airport roadways. On-airport roadways typically have slower operating speeds, more frequent signage and decision points, and a different vehicle mix from off-airport roadways. These characteristics mean that standard HCM techniques may not be sufficient for evaluating on-airport roadways, although it may be possible for HCM methodologies to be used for some situations at the discretion of the planner. Simulation programs are often generally a better choice to model the intricacies of airport roadway systems.

LEVEL OF SERVICE

Highway traffic congestion is expressed in terms of level of service (LOS) as defined by the Highway Capacity Manual (HCM). LOS is a letter code ranging from "A" for excellent conditions to "F" for failure conditions. The conditions defining the LOS for roadways are summarized as follows:

LOS A

Represents the best operating conditions and is considered free flow. Individual users are virtually unaffected by the presence of others in the traffic stream.

LOS D

Represents traffic operations approaching unstable flow with high passing demand and passing capacity near zero, characterized by drivers being severely restricted in maneuverability.

LOS B

Represents reasonably free-flowing conditions but with some influence by others.

LOS E

Represents unstable flow near capacity. LOS E often changes to LOS F very quickly because of disturbances (road conditions, accidents, etc.) in traffic flow.

LOS C

Represents a constrained constant flow below speed limits, with additional attention required by the drivers to maintain safe operations. Comfort and convenience levels of the driver decline noticeably.

LOS F

Represents the worst conditions with heavily congested flow and traffic demand exceeding capacity, characterized by stop-and-go waves, poor travel time, low comfort and convenience, and increased accident exposure.

Courtesy of: McCormick Taylor

***Figure VII-1.   LOS for roadways.***

VII.1.2.3 Curbfronts

Curbfronts are generally evaluated using a curbfront demand model, which uses vehicle length, curbfront dwell times, and the volume of vehicles to determine the approximate length of curbfront needed to serve the vehicular demand.

VII.1.3 Ground Access Plan Development

The data collection and evaluation phases lead into the development of a ground access plan. The flowchart in Figure VII-2 depicts the process of developing a ground access plan. The existing ground access conditions, together with the Airport Master Plan, form the basis for developing a ground access plan. As described previously, the data collected on ground access facilities can be analyzed to determine existing deficiencies in the ground access system. Based on the Airport Master Plan, alternatives for improvements to the ground access system can be developed.

Future air passenger demand for the target analysis year can be used to "grow" existing traffic volumes to future levels. Based on the future traffic volumes, the alternatives that have been developed can be evaluated to determine if they will meet the needs of airport users or if additional deficiencies exist. The alternatives can then be refined, and a preferred alternative selected that will have the capacity to handle expected future traffic volumes, while fitting in with the future plans for the airport.

For additional information, consult *ACRP Report 4* (*48*), which documents recent trends in airport ground access.
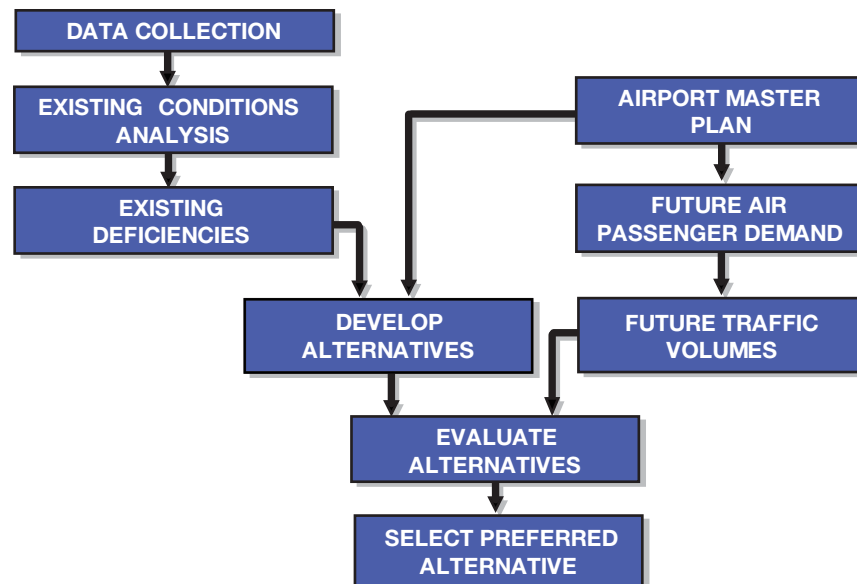
Figure VII-2.   Flowchart to develop ground access plan.

VII.2 Intermodal Connections

There are two types of intermodal connections to be considered in planning for an airport terminal. The first type is a connection with a regional rail or bus system on or near the airport. A rail or bus system connection can be a very important enhancement to the airport's ground access system. Connection to a regional system provides more flexibility for air travelers. It also provides an alternative means of access for airport, airline, and concession employees.

The second type of connection is for on-airport rail and bus transit systems. Transit stations and staging areas for these can be free standing, such as a ground transportation center (GTC), or consist of a series of stations at terminals and other facilities, such as on a people mover system.

VII.2.1 Rail/Transit

The connection of the airport to a regional rail system can provide many benefits for the airport. Stations on or very near to the airport can spread out the access demand, provide a low-cost method for travelers and employees to access the airport, reduce vehicular traffic on the airport, and reduce congestion at the terminals. Two important considerations in planning for an on-airport system are the station and track locations, and the station layout.

Typically only one station of the regional system is at the airport. Many airports have such a connection such as San Francisco, Hartsfield–Jackson Atlanta, Chicago O'Hare and Midway, Reagan Washington, and Minneapolis–St. Paul. Most of these systems are heavy-rail, subway-type systems. The connection in Minneapolis–St. Paul is a light rail system that operates on exclusive rights-of-way or in mixed street traffic. While these systems provide a great alternative to travelers, the most usage of the airport stations tends to be from those who work on the airport property.

Typically a regional system connects to only one station on the airport. This station should be located in the areas of highest passenger demand, such as a terminal. Given the space consider-ations, this might not be possible, so the regional station may need to be connected to a station away from the terminal, such as at a GTC. From here the passengers and employees can walk to the terminals or connect to an on-airport bus or rail system.

New station and track locations should be placed so as not to restrict future growth and flexibility of airport facilities. Station boarding platforms should be wide enough to handle peak period loads. Considerations regarding the location of the station should include the average and maximum walking distance of a user to reach the terminal, ease of access to/from the terminal building, and whether changes in the demand level for the facility varies greatly by time of day.

Station platform configurations can be either center-island or side platforms. Center-island platforms place the passenger boarding/waiting areas between the track alignments, resulting in passengers traveling in each direction on the same platform. Side platforms place the passenger boarding/waiting areas on opposite sides of the track, resulting in passengers traveling in each direction on separate platforms. Side platforms can provide direct access to adjoining areas without level changes while center-island platforms require passengers to make a level change to leave the track area.

VII.2.2 Commercial Vehicles/Transit Staging Areas

There are two main types of on-airport intermodal facilities that have special characteristics. One is for commercial vehicle staging areas for vehicles before being dispatched to the terminal curbfronts. The second type of facility is a GTC, which provides a centralized area for all types of commercial vehicles to pick up and drop off passengers.

VII.2.2.1 Commercial Vehicle Staging Facilities

Vehicle staging facilities are typically used for taxis and limousines that are picking up passengers at the airport. These vehicles proceed to the staging facility to be dispatched to the terminal curbfronts instead of going directly to the terminal. The amount of curbfront utilized by the commercial vehicles can be minimized by regulating the number of commercial vehicles on the terminal curbfront at any given time through centralized dispatching at the staging facility. The extra space gained at the terminal curbfront can be reallocated for other uses. In addition, the amount of commercial vehicle recirculation around the terminal curbfronts while waiting for passengers can be reduced to negligible levels.

Access to a staging facility should be kept to a minimum (one or two access points of off-airport roadways) and can be gated to restrict access to only the commercial vehicles authorized to operate on the airport. Similarly, exits from the staging area should also be minimized. Exit points from the staging area are also typically gated.

Internal layouts to the staging facility vary by the types of vehicles utilizing the lot. Lots can be arranged similar to standard parking lots with individual spaces (either at 90 degrees or angled). Another option, such as the commercial vehicle hold area at Chicago O'Hare, is to have vehicles queue one behind another forming a dispatch line of vehicles. In this configuration, an additional planning consideration would include adding an empty row for bypass and emergency purposes every five to six lanes. Taxi and limousine staging areas are typically separated for operational purposes. Amenities for waiting commercial vehicle operators should also be considered within the facility area. Typical amenities can include restrooms, vending areas, and sitting areas.

Installation of automatic vehicle identification systems also helps manage the commercial vehicle areas using microwave technology and car identification tags. These systems identify, monitor, and control the drivers in the holding area.

VII.2.2.2 Ground Transportation Centers

GTCs provide a centralized location for commercial vehicles to pick up and drop off passengers. A GTC can be located directly at the terminal building with operations separate from the private vehicle pick-up/drop-off locations, such as at Hartsfield–Jackson Atlanta, or at a separate location away from the terminal building. GTC operations separated from the terminal require the

additional capability of transferring passengers to and from the terminal by on-airport transit, but can allow for greater flexibility for expansion of the GTC, if needed.

Access to and from a GTC would have similar requirements to a staging facility. The internal layout of vehicular operations at a GTC would mirror those of a typical curbfront with commercial vehicle operations.

VII.3 Airport Roadway Systems

The airport roadway system comprises a variety of roadways. The roadway system at larger airports can be especially complex. The major types of roadways on an airport are shown in the flowchart in Figure VII-3 and are described in the following subsections.

VII.3.1 Entrance/Exit Roadways (Airport Access Road)

The airport entrance/exit roadway, also known as the airport access road, connects the interior airport roads to the local and regional roadway system. These roadways will need to have the capacity to handle the volume of traffic for now and the future. These access roads can vary from arterial roadways with traffic signal control to limited access/freeway-type facilities at larger airports.

Many large airports have a closed loop access road system. These systems are typically free-flow facilities that provide access to and from the terminal. They have the advantage of providing a smooth transition from the regional/local roads to the terminals. These transition roads allow space to provide signage for terminals and other facilities, and the distance to allow drivers to make decisions. A key feature of closed loop systems is the distance away from the regional/local road connection to the airport. There needs to be adequate distance to provide this type of facility. The following airports have examples of these closed loop systems:

- O'Hare International Airport (Chicago)
- Minneapolis-St. Paul International Airport, Lindbergh Terminal
- Charlotte Douglas International Airport
- Cincinnati/Northern Kentucky International Airport

Some airports are located adjacent to the regional/local roadway system and have no room for a loop road. More airport signage needs to be provided on the regional/local roads. Often the
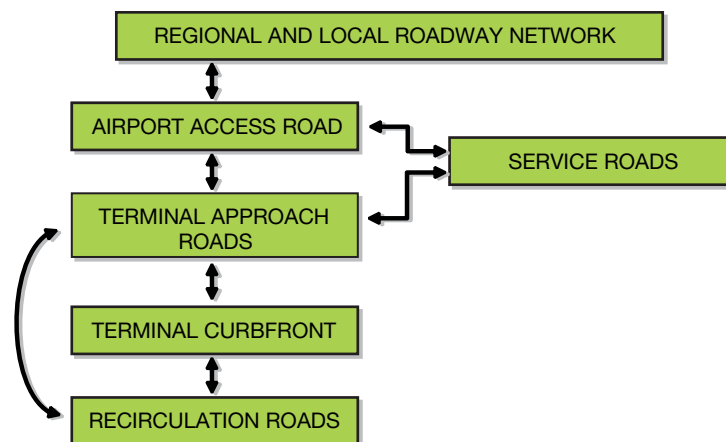
Figure VII-3.   Components of the airport roadway system.

entrances to the airport are under traffic signal control. In this scheme there is also little likelihood of cut-through traffic. The following airports have examples of these systems:

- Midway International Airport (Chicago)
- John Wayne Airport (Orange County)

Some of the considerations in the design and function of the airport access road are the following:

- Provide a transition from regional/local roads
- Provide adequate area for signage—terminals, airlines, rental car parking
- Provide adequate area for decision making
- Efficiently distribute traffic to the facilities on the airport

The airport access road should be designed to function as the gateway for the airport. Its main purpose should be to serve airport traffic. The design should restrict the use of non-airport traffic as much as possible.

VII.3.2 Terminal Approach Roads

The terminal approach roadways are located between the entrance/exit roadways and the terminal curbfront roadways and are part of the airport circulation roadway system. These roads typically have lower operating speeds than the entrance/exit roadway, more ramps and intersections, and more decision points. These roadways distribute traffic not only to the terminals, but also to passenger parking and rental car parking areas as depicted in Figure VII-4.

Some of the operational and design considerations for these roadways are the following:

- Provide a transition to the terminal curbfront roadways
- Provide adequate distance for decision making
- Provide smooth channeling of traffic to the terminal curbfronts and parking
- Provide adequate separation of decision points

VII.3.3 Terminal Curbfront

The terminal curbfront roadways are located adjacent to the terminal curbfronts. These are typically one-way roadways, operating in a counter-clockwise direction. These roadways can have

Figure VII-4.   Roadway system at Lindbergh Terminal of Minneapolis-St. Paul International Airport.

a wide variety of configurations, depending on the layout of the terminal. The major variations are based on the number of levels in the terminal. The most typical layouts are the single-level and two-level or double-level terminals. The single-level terminal can have arrivals and departures on one side or on both sides of the terminal. A double-level terminal typically has arrivals (baggage claim) on the lower level and departures (ticketing) on the upper level. Multiple-level terminal configurations also need to take adequate ventilation considerations into account for the lower level curbfront areas.

Terminal curbfronts at mid-sized and larger airports often have outside curb areas to provide more length of curb, especially for the arrivals level. Many airports—such as Denver, Phoenix, Chicago O'Hare, Atlanta, and Charlotte—use this model. One of the advantages of this system is that private and commercial vehicles can each be given their own curbfront.

Pedestrian crossings are an important component of terminal curbfront roadways. The emphasis on the design and operation of these facilities should be on safety. Optimally, vehicular traffic and pedestrian traffic should be physically separated. However, this separation is often difficult to provide with airport terminals. Most airports have at-grade pedestrian crossings on the curb.

Some of the key points to be considered on the design and operation of curbfronts are the following:

- Lighting
- Speed tables/humps at pedestrian crossings
- Crossing guards
- Adequate transition areas
- Sidewalk/curb width—at least 12 feet; 15 to 20 feet is desirable
- Signage—large type, lighted
- Pavement marking—reflective, raised (where possible), rumble strips
- Ventilation—on lower levels if applicable

VII.3.4 Recirculation Roads

Recirculation roads are typically located at the end of each terminal. They are characterized by tight turning radii and low vehicle speeds. They are typically one-lane roadways. Recirculation roadways are important for the smooth flow of traffic in the terminal area. They should be provided immediately after the terminal. For two-level terminals, recirculation should be provided from each level to each level, if possible. This can be done in a number of ways.

One of the key features of recirculation roadways should be to provide as much flexibility as possible. The following are many of the desirable movements to be provided by recirculation roads:

- Return to same terminal curb
- Go to same terminal, different level
- Go to parking
- Go to next terminal
- Go to previous terminal
- Go to the airport exit

Because many recirculation roads are only one lane, a shoulder should be provided to allow a stalled vehicle to be passed.

VII.3.5 Service Roads

Airport service roads provide access to those areas on the airport that are oriented toward non-passenger–related activities, such as freight loading/unloading areas, employee parking,

links to airfield access, airport maintenance facilities, employee parking, hotels, post office, and general aviation facilities. These roads tend to have low traffic volume with low vehicle operating speeds. They often resemble local streets and typically are one or two lanes in each direction.

One objective in designing these types of facilities is to separate large truck traffic from the passenger-related traffic as much as possible.

VII.3.6 General Guidelines for Airport Roadways

As noted in Section VII.1.2, airports vary greatly in their size and layout, making it difficult to arrive at guidelines for the development of airport roadways.

In addition to the standard roadway and traffic references (HCM, AASHTO Green Book, MUTCD, etc.), some discussion in the airport research literature may prove helpful in planning for new terminals. One summary of guidelines for airport roadways is contained in an FAA White Paper entitled, *Terminal Groundside Access Systems* (*49*). Exhibit 7 of the White Paper gives road and parking performance standards, such as lane width guidelines, terminal curb length guidelines, number of lanes, and vehicles per hour on different roadway types.

A paper presented at a TRB conference, "Intermodal Ground Access to Airports: A Planning Guide—A Good Start" (*50*), contains a table giving typical operating characteristics of airport roadways.

In terms of planning, design, and operating strategies, the following are some general approaches for airport roadways:

- Planning and Design Alternatives
  - Widening—additional travel lanes, widen shoulders to bypass stalled vehicles
  - Median and median dividers
  - Grade separation
  - Dedicated roadways
  - Exclusive turn lanes
  - Lengthening of merge/diverge areas and weaving areas
  - Lengthening of distance between decision points
  - Signage (see Section VII.6)
  - Sight distance improvement
  - Acceleration and deceleration lanes
  - Driveway consolidation
  - Conflict removal
  - Guideline development for maximum grades
  - Grade-separated interchanges
- Traffic Operations Alternatives
  - Traffic signal timing
  - Traffic information signing
  - Traffic surveillance systems
  - Highway advisory radio
  - Demand reduction
  - Alternative modes of transportation
  - Shared ride
  - Spread demand over a larger area (such as separate access points to major generators)

For additional information, consult the results of ACRP Project 07-02, "Airport Curbside and Terminal-Area Roadway Operations."

VII.4 Terminal Curb Requirements

The terminal curbfront on an airport is a complex operating environment. Many types of vehicles approach and stop at the curb, including private automobiles, taxis, limousines, parking lot buses, rental car buses, regional buses and shuttles, and shuttle buses for hotels and motels. Significant curbfront capacity is required to accommodate the maneuvering necessary for vehicles to pull to the curb, stop to load and unload passengers and luggage, and pull away from the curb to merge back into the traffic stream. The curbfront area can be divided into two sections: pedestrian facilities and vehicle facilities.

VII.4.1 Curb Pedestrian Facilities

One part of the curbfront is dedicated exclusively for pedestrians. This part of the environment is on the sidewalk in front of the terminal and on the raised curb islands between travel lanes that are present at many airports. At airports with two-level curbfronts, the upper level is typically used for departing passengers. The sidewalk here is for passenger drop-offs and for curbside check-in. The lower level curb is typically used for arriving passengers. At a minimum, the sidewalk should be wide enough to allow two pedestrians, with luggage, to pass each other comfortably, which is approximately 12 feet. If there are obstructions such as columns, signs, or benches that may impede pedestrian travel, these need to be taken into account when determining reasonable sidewalk width.

Many airports have a pedestrian island between vehicle travel lanes, particularly at the arrivals curbfront, but occasionally at the departures curbfront as well. This island separates the curb lanes into two traffic streams and enables the airport to provide two parallel curbfronts for pick-ups and/or drop-offs, in an equivalent length of terminal building. The curbfront traffic is separated into passenger cars and commercial vehicles (parking shuttles, rental car shuttles, hotel/motel shuttles, etc.) Figure VII-5 shows an example curbfront with a pedestrian island. In this example, the inner curbfront (closest to the terminal building) is designated for commercial vehicles, while the outer curbfront serves private vehicles. Crosswalks are provided between the terminal building and the pedestrian island.
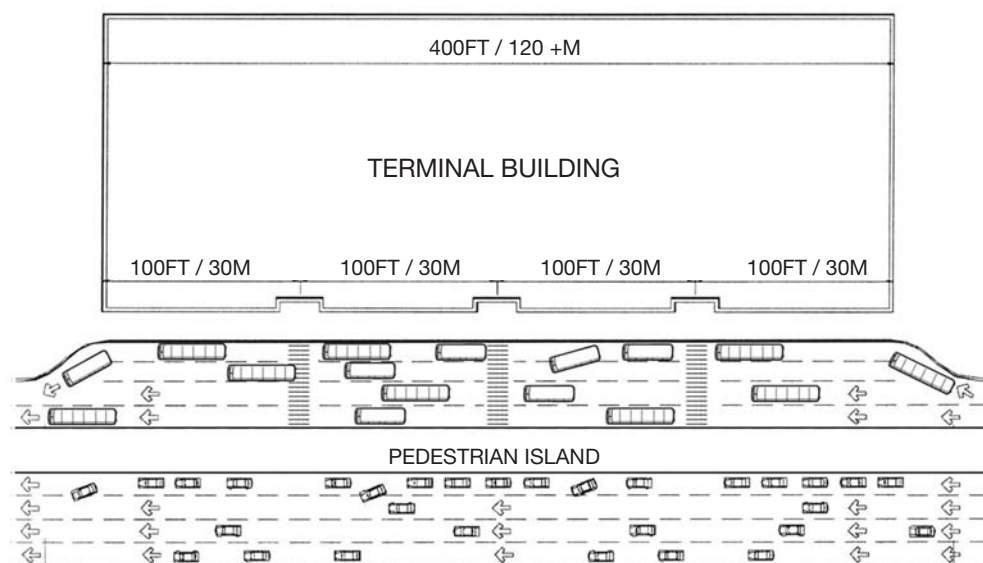
Source: *Terminal Groundside Access Systems,* Fred Silverman, FAA White Paper

Figure VII-5.   Curbfront with pedestrian island.

The location of terminal entrance/exit doors can have an effect on the utilization of the curb, as well as passenger LOS. Observations indicate that cars will tend to stop at the curb no more than three car lengths (50 to 60 feet) from an entrance or curbside check-in, even if this requires double parking. Thus, to make use of the full curb length, entrances should be a maximum of 100 to 120 feet apart as illustrated in Figure VII-5.

Airports vary in their treatment of pedestrian/vehicular crossings. At some airports, grade-separated crossings are provided to access parking garages/lots, rental car areas, and so forth. However, at many airports, pedestrians must cross the curbfront traffic lanes to reach the parking facilities. Well-marked crosswalks should be provided at frequent intervals, aligned with doors to the terminal buildings. Raised crosswalks, or speed tables, provide a level crossing for pedestrians, as well as making drivers physically aware of crosswalks and encouraging slow travel speeds. During peak arrival/departure times, it may be necessary to station police officers at the crosswalks to direct traffic and ensure that pedestrians have safe opportunities to cross the curbfront lanes.

VII.4.2 Curb Vehicle Facilities

The second component of the curbfront consists of the travel lanes dedicated to vehicles. These lanes serve two important purposes that are often in conflict with each other. The first purpose is to provide access to the terminal buildings for private vehicles as well as for commercial vehicles (shuttle buses, taxis, etc.). The second is to move vehicles past the curbfront to their intended destination. These two purposes cause a lot of friction in the traffic flow, resulting in low capacities for curbfront lanes.

The innermost lane (closest to the terminals) is essentially a short-term parking lane, dedicated to vehicles stopping to drop off/pick up passengers. Vehicles pull into an empty space at the curb, load/unload, and pull out. At all but the smallest, low-activity terminals, the second lane is used by both double-parked vehicles, as well as a transition lane, used by vehicles pulling in and out of the curbfront. The third lane is a transition/weaving lane. The fourth lane (and fifth, if one exists, usually at very large airports with multiple unit terminals) is used by vehicles driving past the curb. Therefore, at all but the smallest airports, the minimum number of curbfront lanes is recommended to be four, because it is expected that the second lane may be partially blocked during peak drop-off/pick-up times.

Because of the nature of curbfront facilities, throughput per lane is greatly reduced compared to typical roadway facilities with the same number of lanes. Therefore, there is a need to provide additional curbfront lanes to handle peak loads. Ideally, the roadway will provide enough capacity to accommodate expected traffic volumes even if a through lane is blocked due to maneuvering vehicles and double- or triple-parking.

Curbfront facilities work most efficiently if the curbfront is divided into sections to serve different vehicle types. This limits conflict between different types and sizes of vehicles, as well as spreading the vehicle load throughout the entire curbfront. The curbfront is typically allocated among private vehicles, buses/shuttles, and taxis/limousines. The bus/shuttle section of curbfront may be further allocated into separate areas for rental car shuttles, hotel/motel shuttles, parking shuttles, and so forth. This is particularly useful at the arrivals curbfront, so that patrons waiting for a particular shuttle know where to stand to wait for the shuttle's arrival.

The curb typically runs the length of the terminal building. Passengers tend not to use any curbfront area beyond the end doors of the building. However, some of the vehicle drop-offs (such as commercial vehicles) can be located beyond the end doors. For shorter terminals, pedestrian islands may be necessary to achieve the curbfront capacity needed.

Another important component of curbfront capacity comes in the form of dwell times. At the arrivals curbfront, vehicles will often stop to wait for arriving passengers if sufficient curbfront enforcement is not present. Most airports today enforce a policy of not allowing vehicles to stop at the curbfront unless the driver can see their arriving passenger waiting at the curb. Long dwell times are less of a problem at the departure curbfront, because most drivers drop off their passengers and depart immediately.

Analysis of curbfront facilities requires specialized techniques that take into account the particular variables that are unique to these facilities. Typical HCM techniques are not sufficient to capture the slow speeds, many decision points, dwelling, and frequent stopping/starting that happens at curbfronts. Curbfront analysis models (usually in spreadsheet format) are available that take into account traffic volumes, mode split, vehicle occupancy, and dwell times to determine if sufficient curbfront capacity exists (or is expected to exist, for future scenarios). Simulation models can also be very useful in graphically portraying curbfront operations.

> For additional insight and practical help in performing the determinations and methods described in this section, go to the **Curb Requirements model** provided in *Volume 2: Spreadsheet Models and User's Guide*. This model allows the user to determine the necessary peak hour curbside frontage from observation data such as vehicle split, dwell time, frequency, and vehicle length.

Curbfront analysis can be done for the design hour using hourly traffic data or for smaller time periods, such as 15 minutes, if more detailed data is available. For example, within the design hour, there may be 15-minute peaks that represent 30% of the hourly traffic rather than more evenly distributed activity.

A primary element of curbfront LOS is the ability to find a space for loading or unloading. The probability of finding an empty curb space or having to double park is typically used to describe LOS. Curbside capacity is considered to be the double-parking capacity of the curb as depicted in Figure VII-6. This figure assumes a four-lane roadway with double parking allowed.

LOS is then based on the percentage of the double-parking capacity as follows:

A. Parking demand equal to or less than 50% of double-parking capacity.
B. Parking demand is between 50% and 55% of double-parking capacity.
C. Parking demand is between 55% and 65% of double-parking capacity.
D. Parking demand is between 65% and 85% of double-parking capacity.
E. Parking demand is between 85% and 100% of double-parking capacity.
F. Parking demand exceeds 100% of the double-parking capacity.

For terminal roadways with less than four lanes, other LOS estimating ratios are described in the results of ACRP Project 07-02, "Airport Curbsides and Terminal Area Roadway Operations." As curb parking LOS decreases, there is also a reduction in capacity of adjacent through lanes.

Traffic volumes by travel mode are airport specific and are based on the operations of the airport. Typically, travel modes such as private automobiles, taxis, limousines, and various shuttles serve the curbfront. These peak hour volumes will need to be determined to calculate the curbfront capacity at each location. These volumes can be determined three ways: (1) collect existing data at the location, (2) collect data at a similar airport facility, and (3) estimate the traffic volumes using the following formula: *Estimated Traffic Volumes = Originating Passengers × % Departures or % Arrivals × Curbfront Mode Split.*

LOS A

Drivers experience no interference from other vehicles or pedestrians. Motorists arriving at the airport terminal can stop adjacent to the curb at preferred locations. Demand is equal to or less than 0.50 of the double-parking capacity of the curbside. Capacity of adjacent through lanes is unaffected.

LOS B

Relatively free-flow conditions, although double-parking can be observed at some curbside locations (i.e., baggage check-in, major entrance/exit points). Demand is between 0.5 and 0.55 of the double-parking capacity of the curbside. Capacity of adjacent through lanes is virtually unaffected.

LOS C

Double-parking near doors is common and some intermittent triple-parking may occur. This level of service is appropriate for peak period design conditions at major airports. Demand is between 0.55 and 0.65 of the double-parking capacity of the curbside. Capacity of adjacent through lanes is reduced by approximately 5% due to the increased frequency of double-parking.

LOS D

Triple-parking occurs more frequently and vehicle maneuverability is somewhat restricted. Intermittent vehicle queues may form both in the through lanes and at the entrance to the curbside area. Demand is between 0.65 and 0.85 of the double-parking capacity of the curbside. Capacity of adjacent through lanes is reduced by over 20% due to the increased frequency of double- and triple-parking.

LOS E/F

LOS E—Motorists experience delays and queues along the length of the curbside. Both congestion and double- or triple-parking are evident throughout the curbside area. Momentary breakdowns in operation occur as traffic in the through lanes is increasingly delayed by vehicle maneuvering in and out of the parking lanes. Demand is between 0.85 and 1.0 of the double-parking capacity of the curbside. Capacity of adjacent through lanes is reduced by over 35% due to the increased frequency of double- and triple-parking.

LOS F—Motorists experience significant delays at the curbside entrance and along the length of the curbside. Parked vehicles are unable to leave the curbside due to stopped vehicles in adjacent lanes. Demand exceeds 1.0 of the double-parking capacity of the curbside. The flow of vehicles in all lanes frequently comes to a halt.

Note: Assumes a 4-lane curbside roadway where double parking is allowed.

Figure VII-6.   Curbfront LOS descriptions.

Table VII-1.   General headway times by travel mode.

Travel Mode	General Headway Times (minutes)
Rental Car Shuttles (individual companies)	2 - 4
Rental Car Shuttles (consolidated)	3 - 5
Hotel Shuttles	5 - 10
Other Shuttles	5 - 15 (varies by type)
Buses	30 - 60

Curbfront mode split can be determined by passenger survey on mode of arrival to the airport (which is typically how they will also leave the airport) and party size. To determine the number of shuttles or other buses, the type of rental car facilities and number of local hotels providing airport shuttles and number of bus or shuttle services providing service to the airport must be established. Furthermore, there will be fewer shuttle trips if a consolidated rental car campus is planned rather than rental car companies running individual shuttles. If no specific headway data is available, the general headway data shown in Table VII-1 can be used:

To determine the curbfront traffic volume for one of these modes, multiply the number of companies servicing the airport by the headway and convert to vehicles per hour.

Dwell times should be collected during the peak hour to determine the maximum utilization of the curbfront. As stated earlier, a main component of dwell time is enforcement. When there is strict enforcement of the curbfront, dwell times are typically shorter than when enforcement is not as strict. If existing data is available, that would be best; however, data can be collected at a similar airport facility or the dwell times may be used. Table VII-2 shows dwell times presented by travel mode with the assumption of relatively strict enforcement.

One thing to consider is that arriving and departing vehicles of the same travel mode may not have the same dwell times.

Vehicle length helps determine the amount of room on the curbfront that the vehicles use when parked. Table VII-3 provides general lengths to be used in the analysis. These lengths include additional room to compensate for the space between vehicles on the curbfront.

These values can be used in the analysis instead of measuring specific lengths at the airport. However, if the airport has other travel modes at the curbfront, then specific lengths may need to be determined for that travel mode.

Before determining the curbfront length, the allowance of double parking must be considered. If double parking will be allowed, it must be factored into the curbfront utilization. The main benefit of allowing double parking is that there is more curbfront for vehicles to utilize.

Table VII-2.   Dwell time by travel mode.

Travel Mode	Dwell Time (minutes)
Private Auto	2 - 4
Taxis	1 - 3
Limousines	1 - 3
Rental Car Shuttles	2 - 5
Hotel Shuttles	2 - 4
Other	varies

Table VII-3.   Vehicle length by travel mode.

Travel Mode	Length
Private Auto	22FT / 7M
Taxis	22FT / 7M
Limousines	50FT / 15M
Rental Car Shuttles	50FT / 15M
Hotel Shuttles	40FT / 12M
Other	varies

Source: Kimley-Horn and Associates, Inc., All rights reserved.

For example, an airport curbfront may be designed to allow double parking during peak times to help meet the added demand. However, double or even triple parking contributes significantly to the congestion of the curbfront, sometimes blocking vehicles in inner lanes and overall impeding the through travel lane of the curbfront and increasing the vehicle congestion that pedestrians will need to travel through to access parking lots on the other side of the curbfront.

Another factor to consider is whether a multiple stop factor is appropriate for the curbfront. A multiple stop factor should be applied when a vehicle, typically shuttles, will stop multiple times along one curbfront. Multiple stops are most common at airports that have a shared curbfront between multiple terminals and the walking distance is too far to expect passengers to travel to a central location with their luggage.

Considering all of these factors, the desired curbfront utilization must be determined. Once this has been established, the required size of the curbfront can be determined by summing the demand of all modes of travel. Demand can be calculated by multiplying volume × dwell time × length of vehicle, then converting it to demand by hour for each mode. Total demand compared to the desired curbfront utilization will result in required curbfront length.

VII.5 Parking Facility Requirements

Parking facilities are typically provided for the following users:

- Passengers
- Employees and tenants
- Rental cars

VII.5.1 Passenger Parking

Demand varies greatly for airport parking by time of day, day of the week, and season. Typically demand peaks around holidays, such as Thanksgiving, Christmas, and Spring Break. Airport operators ultimately determine policies controlling the number and type of parking facilities to be provided. Typically there are five types of passenger parking facilities for an airport:

- **Terminal parking:** Close-in parking facilities, in relation to the terminal building, provide the most convenient parking spaces for passengers. These facilities can provide short-term and long-term spaces. Short-term patrons usually remain at the airport for time periods of less than 4 hours (*51*). Long-term patrons, airline passengers parking during their trip, often remain for several days. While short-term parking can account for the majority of parking activity at an airport, the higher turnover rate for space requires fewer parking spaces than the long-term facilities.

- **Remote parking:** Remote parking facilities typically cater to the long-term parking patrons but differ from the terminal parking facilities in that the lot location is at a distance away from the terminal building. Remote parking lots require on-airport transit capabilities to transport passengers to/from the terminal. Remote parking lots typically have a much lower cost than the terminal parking facilities, therefore, costing the passenger less over a longer duration stay.
- **Off-airport parking:** Off-airport parking facilities are essentially the same as remote parking facilities but are usually operated outside of airport property by a non-airport entity. Transit capabilities to/from these facilities are handled by the private operators of the lots. These private operators drop off and pick up their patrons directly at the terminal curbfront or at a GTC, if one is present and is allowed by the airport operator.
- **Valet parking:** Valet parking is provided at many airports. Departing passengers leave their vehicles to be parked either at the terminal curbfront or at one of the close-in terminal parking lots.
- **Cell phone lots:** Cell phone lots have recently sprung up at airports all over the United States, especially at airports experiencing significant traffic congestion at the curb. These lots are often placed along the entrance road to the terminal to be more visible to drivers entering the airport.

These lots provide significant advantages to the airport and to the driver. They reduce vehicles waiting on the curb and reduce recirculation traffic. The driver is able to pull off of the entrance road and comfortably wait for a call on his/her cell phone from the arriving passenger being picked up. Some airports have even installed flight information displays to let the driver know when flights are expected to arrive.

Cell phone lot size should be designed to reflect the type of users the airport has: an O&D airport will need more spaces than a primarily connecting passenger airport. These lots also need to be an easy choice for the person picking the passenger up, by being easy to access, having good signage to the location, and being in proximity to the location of flight arrivals, etc.

The number of passenger and public parking spaces at an airport varies greatly depending on the policies of each airport operator (See Table VII-4). Local conditions for each airport should determine the ultimate number of spaces to meet anticipated demand. While there is a great deal of variation based on local conditions, passenger parking demand has been demonstrated to be related to the number of originating passengers (*50*). As a general rule of thumb, parking supply should range from 900 to 1,400 spaces per million enplaned passengers, with 25% to 30% of spaces designated for short-term parking (*49*).

To avoid long walking distances for passengers, a maximum distance should be established between parking spaces and the terminal building (close-in facilities) or transit pick-up/drop-off

Table VII-4. Examples of rule-of-thumb passenger parking*.

Originating Enplanements	Parking Supply	Approximate Number of Short-Term Parking Spaces	Approximate Number of Long-Term Parking Spaces
500,000	450 - 700	100 - 200	350 - 500
1,000,000	900 - 1,400	225 - 425	675 - 975
1,500,000	1,350 - 2,100	325 - 625	1,025 - 1,475

*Exact parking space numbers depend on the type of flights the airport services

locations (remote facilities). A typical maximum walking distance for passengers is between 900 and 1,000 feet.

Parking structures and lots should be planned to enhance pedestrian safety, circulation, and wayfinding and should recognize that most parking patrons are infrequent users of the facility. To prevent runaway baggage carts and to accommodate wheeled baggage, parking areas/garages should be level. As a result, a garage configuration with parking on vertical circulation ramps is not recommended (*51*).

Pedestrian connectivity between close-in parking facilities and the terminal should avoid having passengers walk across active terminal roadways. To increase pedestrian safety and avoid pedestrians crossing roadways, a passenger walkway (elevated bridge or tunnel) that connects the parking facility and the terminal is recommended.

Revenue control plazas for both entry and exit movements at the parking facilities should provide enough lanes to accommodate the existing and future demand based on the system(s) in use. Sufficient vehicular queuing space is also needed at the control plazas to avoid conflicts with free-flowing traffic on terminal roadways (for entering vehicles) or interfering with traffic circulation within the lot (for exiting vehicles).

Parking pricing schemes are important and should be based on the facility type and on the user market. For example, long-term parking is often provided in more remote lots at a lower price when compared with hourly or short-term parking areas. Also, if prices are too high, users may not park in the closer areas; if prices are too low, users may overuse closer areas causing them to be full for users that need them.

VII.5.2 Employee/Tenant Parking

Similar to passenger parking, airport operators ultimately determine policies controlling the number and type of parking facilities to be provided for employee parking. Employee parking facilities can be either close to the terminal or in remote lots. Close-in employee parking is typically located in either the short-term or long-term passenger areas, but usually in segregated locations from passenger parking areas. Remote parking lots require the on-airport transit capabilities to transport employees to/from the terminal or other on-airport destinations. Employee transit is typically on a separate system than passenger transit in similar facilities.

Because employee parking is usually implemented on a permit basis, entry/exit plazas and vehicular queuing areas at the entry/exit locations can be significantly reduced compared to the passenger parking facilities.

The number of passenger and public parking spaces at an airport varies greatly depending on the policies of each airport operator. Local conditions for each airport should determine the ultimate number of spaces to meet anticipated demand. As a general rule of thumb, parking supply should range from one space per 2.5 to 3.0 employees or 250 to 400 spaces per million enplanements (*49*). In comparison to passenger parking ratios, the employee space ratio is lower due to the shift nature of airport employment.

VII.5.3 Rental Car Parking

Almost all airports have rental car (RAC) companies on the airport that provide drop off and pick up of rental cars. At small- and medium-sized airports, the rental car ready-return (R/R) lots are typically located within walking distance of the terminal. Depending on the number of RAC companies, R/R spaces, and lease agreements, the R/R lots may be combined or separated. Spaces may be common use or dedicated to individual companies.

At larger airports, rental car facilities are often located at remote sites on the airport, away from the terminal. This location often requires a shuttle bus to pick up or drop off passengers. There are two main types of remote rental car operations:

- The first type consists of facilities that are operated by individual rental car companies. Each company has separate office and maintenance facilities, and R/R parking for their cars. These facilities can be located near each other or can be in separate areas. Each company has its own shuttle bus to bring passengers from the terminal to the facility.
- The second type consists of a consolidated RAC campus. This facility is typically a joint project, sponsored by the airport operator and the rental car companies. Often a surcharge on cars rented at the airport is levied to pay for such a facility. The consolidated facility is typically located on airport land. All of the on-airport companies have their own counter and their R/R areas in this facility. A single bus fleet serves all of the companies on this campus. Airports that have consolidated campuses operating include Cleveland Hopkins International, Phoenix Sky Harbor International, Fort Lauderdale/Hollywood International, and Houston George Bush Intercontinental. Some airports are considering or planning for people mover access to these facilities as has been done in San Francisco.

VII.6 Roadway Circulation and Wayfinding

There are many decision points along a typical airport roadway. That, combined with the fact that many passengers and visitors do not regularly travel these roads, makes clear, understandable signage especially important. Passenger wayfinding through the airport environment brings several key factors into play, as discussed in the following paragraphs.

VII.6.1 Circulation Flow and Analysis

Development of a signage system should begin with identification of major circulation patterns through the airport environment. These patterns can be broken down as required for specific locations but can generally be divided into inbound and outbound movements for major airport users (visitors, passengers to parking, rental car users, employees, etc.). Primary and secondary circulation routes through the airport can be quickly identified through the analysis of the planned roadway network.

VII.6.2 Decision Points

Along the major circulation routes, decision points can be identified at locations requiring direction changes and path choice alternatives. Identification of these decision points helps to locate critical areas were wayfinding signage is needed to assist the roadway users in navigating the environment.

VII.6.3 Sign Locations

Based on the circulation patterns and decision point location along with sight lines for drivers, directional signs can be located before major decision points to allow for adequate time for drivers to react in a safe manner.

Wayfinding signs for airport vehicular circulation should be consistent across the property in terms of legibility, visibility, formatting, and terminology/symbology. Signage standards or guidelines within the airport environment can provide this consistency, allowing for updates to existing and future signage, and can be adapted to incorporate developing technologies. Consistent formatting, terminology for airport facilities, and symbology for airport locations can provide the driver with simplified pieces of information encountered throughout the environment.

Legibility and visibility depend primarily on assumed driver reaction times. As the number of lanes on a given roadway increases, driver reaction times tend to increase because it takes longer to accomplish a desired vehicle movement across multiple lanes. In the same manner, an increase in the speed of a given roadway facility decreases the amount of time a driver has to react. The driver needs to process the same amount of data in a shorter timeframe, therefore increasing reaction time. As anticipated driver reaction times increase, both letter heights on wayfinding signs and sign placement distance before decision points need to increase.

While signage packages can be specific and unique to each airport, traffic control devices (including signs, traffic signals, and pavement markings) installed on any street, highway, or roadway open to the traveling public are subject to the national standard for all traffic control devices as included in the MUTCD. The MUTCD is published by the Federal Highway Administration, most recently published in 2003. Additional guidance may be found in the results of ACRP Project 07-06, "Wayfinding and Signing Guidelines for Airport Terminals and Landside."

Of additional benefit in wayfinding within the airport environment is the use of Intelligent Transportation Systems (ITS). On freeway systems, usage of ITS is primarily visible to drivers through variable message signs that update drivers on traffic and congestion conditions in busy metropolitan areas. In an airport environment, this type of variable message signage system can be implemented to inform drivers of parking conditions at lots throughout the airport, identify congestion areas at the terminal curbfronts or other congested locations, and suggest alternative routes or destinations if available.

VII.7 Landside Security

VII.7.1 Access Roadway and Terminal Curbside

While approach roads are not yet within the TSA's immediate regulatory jurisdiction, any incident on or near airport property is of concern, whether for purposes of liability or its potential as a precursor to a security related or criminal event. Incidents are also of concern in areas where the airport may have direct connections with light rail, subways, buses, or other mass transit and such indirect connections as passengers and baggage arriving from marine terminals, hotels, and casinos.

The TSA has considered seeking jurisdiction to transition areas at airports served by other means of ground or water transportation, without defining the characteristics, location, and boundaries of those areas. Such areas could include public roads, but no such regulations have yet been defined or implemented.

Technical solutions here, as in the terminal lobbies, are limited by the need to keep the approach and departure roads fully open and accessible to the general public. Perimeter-monitoring technologies such as CCTV cameras can also apply to roadway security and can take advantage of video analytic capabilities. Condition-specific analytics can be applied here, with public areas having the highest variability of possible scenarios to be monitored and the resulting need to prioritize potential events and set thresholds to differentiate between normal and anomalous activities in order to limit false alarms, as well as having an alternate set of rules when threat levels and operational requirements change.

As the terminal is made more secure, the vulnerability of areas on the approach roads, parking areas, and curbs may increase. The terminal curb is the first point of direct public and passenger contact with the terminal and presents the most obvious situations and conditions that expose the airport to a VBIED.

Airports are configured for the rapid processing of large concentrations of incoming and outgoing passengers at the curbside, which presents both a security and safety concern, especially during peak times. The TSA has provided recommended procedures for passenger drop-off and pick-up at the curb, based on a limited amount of time a vehicle can be stopped at curbside. This policy provides no real security whatsoever, as an explosive-laden vehicle can stop at curbside and the driver can exit the vehicle, walk away, and detonate the explosive remotely.

Roadway vulnerabilities in high threat conditions are commonly addressed by jersey barriers that create a zigzag path for approaching high-capacity vehicles to maneuver, reducing both the speed and kinetic effect of a blast threat. Clearly, such barriers are temporary measures, not primary elements of design, although some attention may be paid to roadway layout that diminishes attack speeds, such as angular turns or high curbs.

Heavy bollards, often designed as permanent decorative planters or benches at the curbside in front of the terminal, can stop, or at least minimize, vehicle penetration into the public lobby. They should not be in the form of trash containers that can conceal explosives, particularly those made of stone aggregate, which themselves present dangers of fragmented shrapnel-type debris.

When there are multi-level roadways that are not physically protected from vehicular attacks, airports should consider hardening the lower level supporting columns or façade to prevent severe damage or collapse.

VII.7.2 Multi-modal Connections

While many airports have so-called multi-modal connections with other forms of public transport such as buses, trains, and subways, the security interface between them is relatively straightforward; there are little or no security measures imposed on those vehicles or passengers before their arrival at the airport, so all arrivals must remain on the public, non-secure landside before any security screening, and preferably well removed from the terminal. In this sense, it is no different than any curbside arrival of buses, taxis, or other unscreened persons and vehicles. Future technology advances may eventually allow procedural changes in how those arrivals are channeled into the terminal, including the possibility of remote check-in terminals with secure transport to the operational terminals. In either case, they must still first be brought into pre-screening public areas for processing of tickets and baggage, as well as separation of passengers from the general public.

The most common airport interface with another mode of transportation is when a wide range of trucks of every size and description arrive, bringing construction materials, concession goods, cargo, fuel, catering, maintenance requirements, and more. Procedural aspects of those arrivals are addressed above in the vehicle checkpoint section, but their points of arrival share some common vulnerability with other areas on the public side of the terminal:

- Loading docks and shipping/receiving areas for large unscreened vehicles are recommended to be at least 50 feet from utility rooms, utility mains, and service entrances such as electrical, telephone/data, fire detection/alarm systems, fire suppression water mains, cooling and heating mains, and so forth. When located where vehicles are driven or parked under the building, consider hardening the entire area, and venting the room outward.
- Exterior doors and window systems (glazing, frames, anchorage to supporting walls, etc.) can be hardened to mitigate effects of a VBIED causing flying glass and debris. However, hardened glazing offers little protection against an aggressor walking inside the entry doors with unscreened luggage or parcels, especially those with international flights, when passengers often travel with oversized luggage.
- Restrooms in airport public areas, as well as service spaces and unscreened access to stairwells in non-secure landside locations, should be placed to avoid concealment of criminal activities,

and if possible not be adjacent to critical facilities such as emergency UPS systems; heating, ventilation, and air conditioning systems; communications rooms; utilities; elevator shafts; and so forth.

VII.7.3 Parking Facilities

Security measures in airport parking lots tend to concentrate first on common criminal behavior such as theft, assault, and vandalism. Design approaches might include attention to such measures as appropriate lighting for CCTV, emergency alarms and call boxes, accessibility for emergency response vehicles, and minimization of concealment locations in enclosed stairwells or remote corners in parking garages.

From an anti-terrorism perspective, design of parking facilities adjacent to terminal buildings will almost certainly require coordination with a TSA risk assessment and should accommodate the potential for vehicle inspection facilities during high alerts.

Vehicle screening at elevated threat levels also introduces significant labor and operational costs well beyond the screening itself. Wherever vehicle screening occurs, it will typically create backups on the public approach roads—an early airport planning issue. Once instituted, whether remotely or close in, vehicle screening requires space for trained manpower to accomplish the process on multiple vehicles of all sizes simultaneously; weatherization and computer/communications in remote booths for people and equipment; persons, space, and equipment to deal with rejected or suspect vehicles, including alternate routes for their removal (including large trucks) away from the terminal; and additional remote parking and dedicated transport to accommodate diverted passengers and baggage. Commercial deliveries requiring screening are considered independently, at separate locations such as loading docks or perimeter gates that handle all screening of deliveries remotely.

Terminal parking facility design can address certain measures for blast mitigation up to a point, but they rapidly become cost prohibitive, labor intensive, design antithetic, and operationally intrusive. Security costs that go beyond basic principles of design and construction should be weighed against a realistic threat and vulnerability assessment, because their costs are significant, and their contribution to security are generally speculative with respect to the probability that a significant event will happen at this airport.

In December 2002, TSA reviewed the agency list of "unnecessary rules" and lifted the so-called 300-foot rule in contingency plans. It was essentially a system-wide formulaic ban on any unknown vehicle parking within 300 feet of the terminal building at Category X, I, and II airports. Category III and IV airports were not required to conduct a blast analysis or develop a Bomb Incident Prevention Plan. In its place TSA instituted a series of operating procedures intended to provide relief from the 300-foot approach by adding flexibility when tailoring an individual airport's security program. Each local plan is based on an approved blast analysis performed by a certified engineering firm and is to be instituted when the Department of Homeland Security threat level is elevated to "orange." Without such an analysis, the 300-foot rule remained in effect at larger airports.

Also, note that designs in some geographic areas can reap dual structural and security benefits when state and local building codes require earthquake resistant measures to prevent or mitigate damage from collapse.